Pain severity and e-cigarette health literacy: the moderating role of sex

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ABSTRACT: Although electronic cigarette (e-cigarette) use has increased among adults in the United States, there is still little knowledge of factors that may influence e-cigarette use or beliefs about use. Prior research suggests that health literacy plays an important role in e-cigarette beliefs, including perceived benefits and risks of e-cigarette use, as well as e-cigarette dependence. Yet, limited work has examined risk factors of poor e-cigarette health literacy. From a biopsychological perspective, sex and pain severity represent two constructs that may impact e-cigarette health literacy. To date, however, no research has investigated differences in e-cigarette health literacy across pain, sex, or their interrelation. Thus, the present study was conducted to evaluate the interactive effect of pain severity and sex on e-cigarette health literacy. Participants included 319 current, adult e-cigarette users (60.5% female, $M_{age} = 36.82$ years, $SD = 10.62$). Findings supported a significant pain by sex interaction, such that pain related to e-cigarette health literacy among women ($b = .10$, $SE = .03$, $P < .001$), but not men ($b = .01$, $SE = .03$, $P = .60$). The present findings suggest that pain may uniquely impact the degree to which women, but not men, seek and understand information on e-cigarettes.

KEYWORDS: pain, sex, health literacy, e-cigarettes, nicotine, addiction

Electronic cigarette (e-cigarette) use has increased rapidly since they were first introduced in 2006.[1,2] E-cigarettes are commonly believed to be less harmful than combustible cigarettes.[3,4] However, there are health risks associated with e-cigarette use,[5-7] including respiratory illness,[6,7] inflammation,[8] and bone and tissue damage.[5,9] Additionally, although e-cigarettes are often used as combustible smoking cessation aids among adults,[10] findings are presently inconclusive for the efficacy of these devices[11,12] and some work suggests they may prolong nicotine addiction and combustible cigarette use.[11,13] Recognizing the complexities of substance use, one important "next step" in this line of research is to determine the role of individual difference factors in e-cigarette use and beliefs about use.

An individual factor that may be related to e-cigarette use processes is the experience of pain. Pain is a complex phenomenon influenced by a range of biopsychosocial factors.[14] Combustible cigarette research has documented a reciprocal relation between pain and smoking such that they frequently co-occur and influence one another.[15-17] For instance, pain has been identified as a motivator for cigarette use.[15,18] Conversely, smoking has been identified as a risk factor for more severe pain[19-21] and has been implicated in the onset of chronic pain.[22,23] Pain has also recently been linked to e-cigarette use and beliefs that maintain use. Specifically, greater pain severity is significantly related to increased e-cigarette dependence, more perceived risks of e-cigarette use, and greater perceived barriers to e-cigarette cessation among e-cigarette using

adults.[24] Other work has observed that more severe pain and greater sensitivity to somatic perturbation (ie, anxiety sensitivity) are synergistically related to e-cigarette dependence as well as perceived risks and benefits of e-cigarette use.[25] Collectively, initial research highlights the potential importance of pain in terms of e-cigarette use and beliefs about use, but the range of e-cigarette processes thus far studied is relatively narrow in scope.

Past work also has not explored the role of sex in pain-e-cigarette associations. Some recent research has evaluated sex differences in e-cigarette behavior and beliefs.[26,27] Findings from this work suggest that men, compared to women, are more likely to use e-cigarettes[26,28] and report greater rates of combustible smoking cessation when using e-cigarettes.[29] Further, women, compared to men, report greater expectancies for e-cigarette use to mitigate negative mood and to suppress appetite.[27] However, compared to women, men report greater positive expectancies for e-cigarettes, such as enjoyment, energy, social facilitation, and taste.[27]

There has been little exploration of pain or sex in terms of health literacy among e-cigarette users. Health literacy reflects the ability to obtain, understand, and use information to make decisions regarding health and medical care.[30] Prior work has documented that lower health literacy is related to higher health care costs, utilization of health care services (eg, hospitalization rates), and poorer response to medical treatment.[30] Indeed, individuals with lower health literacy are more likely to

have worse physical function and mental health, experience limitations in activity due to their physical health, and suffer from pain that interferes with everyday work activities.[31] Among combustible cigarette smokers, previous research has documented that lower health literacy is related to higher nicotine dependence, less knowledge about the health risks of smoking,[32] and lower smoking risk perceptions.[33] To date, only one study has examined e-cigarette specific health literacy (health literacy that is specific to use of e-cigarettes), and it found that greater e-cigarette health literacy was associated with higher perceived benefits and risks of e-cigarette use as well as greater e-cigarette dependence.[34] Like other research on health literacy,[35,36] these data are the first to highlight the potentially important role of e-cigarette health literacy. Yet, there is a need to broaden our understanding of e-cigarette health literacy because this construct may influence decision-making about patterns of use, attempts to change e-cigarette use, and the ability to act on and understand the advice of health professionals in terms of e-cigarette use.

Together, the present study sought to evaluate the main and interactive effects of pain severity and sex in terms of e-cigarette health literacy. It was hypothesized that greater pain severity among women, compared to men, would be related to lower e-cigarette health literacy. This hypothesis was driven by past work that suggests women, relative to men, report more pain[37] and may be more likely to experience difficulties in seeking, understanding and using information about e-cigarettes because of a propensity to use to cope with pain-related distress.[24,25] That is, they may be more likely to focus their attention on the coping-related functions of e-cigarette use, thereby showcasing lower levels of e-cigarette health literacy relative to men.

Method

Participants

The present study included 319 e-cigarette users (60.5% female, $M_{age} = 36.82$ years, $SD = 10.62$). Participants were recruited nationally via an online survey, panel program. Study eligibility criteria included being 18 to 65 years old, e-cigarette use within the past 30 days, reporting pain on at least one area of the body, and being able to provide informed consent. Exclusion criteria included being younger than 18 years or older than 65 years, being a non-English speaker (to ensure comprehension of the study questions), and the inability to give informed, and voluntary consent to participate.

The present sample consisted of predominately White/Caucasian (78.1%) individuals, followed by 14.4% Black/African American, 3.4% Asian, 1.9% Native American/Alaska Native, and 2.2% other. Regarding education, 26.0% of the participants received a high school diploma or equivalent, 24.8% completed some college, 13.5% earned an associate degree, 16.3% earned a bachelor's degree, 12.5% completed at least some graduate school, and 4.7% did not graduate high school or earn an equivalent diploma. More than half of the sample indicated they were married or living with someone (63.0%). The median income bracket fell within the range of $35 000 to $49 999.

Measures

Demographics questionnaire. Participants provided their sex (0 = Male, 1 = Female), race, marital status (1 = Married or living with someone, 2 = Widowed, 3 = Separated, 4 = Divorced/Annulled, 5 = Never married), age, educational level (1 = Grade 6 or less to 8 = Graduate or professional degree), and annual income (1 = $0-$4999 to 8 = $75 000 or higher).

Electronic cigarette smoking history questionnaire. The electronic cigarette smoking history questionnaire (EC-SHQ) is a 28-item self-report measure that assesses an individual's e-cigarette use history.[34] This questionnaire includes items pertaining to frequency of use (eg, Think about your e- cigarette use during the last month, how many days did you use an e-cigarette?), age at onset, dual tobacco use (eg, Do you currently use cigarettes? [1 = Yes, 2 = No]), and number of e-cigarette quit attempts. The EC-SHQ has been successfully used in previous e-cigarette studies (see Zvolensky et al[38]).

The short form health survey – 12. The short form health survey (SF-12[39]) is a 12 item self-report measure of general mental and physical health. Consistent with previous research, a single item was used to assess perceived health (ie, In general, would you say your health is: 1 = excellent to 5 = poor).

Hunter integrated pain service: brief pain inventory. The brief pain inventory[40] is an eight-item measure that assesses an individual's pain severity. Respondents first indicate the areas of their body where they experience pain. Next, respondents rate the severity of pain they experience from 0 (No pain) to 10 (Pain as bad as you can imagine). The brief pain inventory has demonstrated strong reliability, internal consistency, and construct validity.[41] The current study utilized the pain severity index, which is calculated by averaging the scores for items 2 (rating of pain at its worst in the last week), 3 (rating of pain at its least in the last week), 4 (rating of pain on average), and 5 (rating of pain right now). The pain severity index evinced good internal consistency ($\alpha = .88$).

Penn state electronic cigarette dependence index. The Penn state electronic cigarette dependence index is a 10-item self-report questionnaire used to examine e-cigarette dependence.[42] Participants are asked to provide information on the strength of urges to use (eg, Do you ever have strong cravings to use an e-cigarette?), waking and night use (eg, Do you sometimes awaken at night to have a e-cigarette?), number of times that an individual uses an e-cigarette (eg, How many times a day to you usually use an e-cigarette?), difficulty quitting (eg, Did you feel more irritable because you couldn't use an e-cigarette?), and experience of craving and withdrawal symptoms (eg, Is it hard

to keep from using an e-cigarette?). Previous work supports the total score as a valid and reliable index of e-cigarette dependence (α = .64).[42]

E-cigarette health literacy questionnaire. The E-cigarette health literacy (ECHL) questionnaire is a 5-item self-report measure.[34] This measure was adapted from the all aspects of health literacy scale (AAHLS[43]). E-cigarette health literacy questionnaire measure includes items pertaining to the frequency at which a patient actively seeks health care information (eg, When you talk to a doctor or nurse, do you make sure they explain anything that you do not understand about e-cigarettes?), verifies such health care information (eg, How often do you try to work out whether information about e-cigarettes can be trusted or is accurate?, When you talk to a retailer about e-cigarettes, do you make sure you understand all the chemicals contained in your e-liquid?), seeks various sources of information regarding e-cigarettes (eg, Are you someone who likes to find out lots of different information about your e-cigarette?), and actively attempts to understand how e-cigarettes work (eg, When you talk to a retailer about e-cigarettes, do you make sure you understand how the calibration of your e-cigarette and battery power to burn the e-liquid?). Items were assessed via a 4-point likert scale from 0 (Never) to 3 (Often). A mean of the items was utilized in the present study (α = .85).

Procedure

Participants were recruited nationally via Qualtrics Inc. Interested participants were screened for eligibility and directed to the online, anonymous survey. Prior to completing the survey, participants provided informed consent. The survey took approximately 30 minutes to complete, and participants were compensated with credit through their Qualtrics account commensurate to their participation. Each participant was given the option to choose their preferred form of compensation based off their credit, however, the total amount for completing the survey remained the same ($8.50). The study protocol was approved by the Institutional Review Board at the institution supporting this research.

Analytic strategy

Analyses were conducted using SPSS version 25. First, sample descriptive statistics and zero-order correlations among study variables were examined. Second, to evaluate main and interactive effects of pain severity and sex, four separate hierarchical regression analyses were conducted for e-cigarette health literacy, the dependent variable. Covariates were entered in the first step of each model and included age, income, education, dual combustible cigarette use, e-cigarette dependence, and perceived health status, consistent with past work.[34,38] Pain severity and sex were then simultaneously entered in the second step of each model. Finally, the interaction of pain severity and sex

was added in the third step. Planned post-hoc simple slope analyses were conducted using the PROCESS macro[44] to examine associations between pain severity and health literacy across sex (0 = male; 1 = female).

Results

Descriptive statistics

Most participants reported daily e-cigarette use (61.1%), and on average, participants reported using an e-cigarette 8 ($SD = 10.10$) times per day. A low level of e-cigarette dependence was observed in the present sample ($M = 6.98$, $SD = 4.02$; Foulds et al., 2014)[42]. Additionally, more than three-fourths of the participants (75.9%) reported dual cigarette use. Among those who reported dual cigarette use, participants reported smoking an average of 12.4 ($SD = 8.4$) cigarettes per day, 18.6 ($SD = 5.3$) years old when they started smoking cigarettes daily and being a daily cigarette smoker for an average of 17.2 ($SD = 10.81$) years.

Bivariate correlations are presented in Table 1. Pain severity did not significantly differ across sex ($r = −.05$; $P = .35$). Pain severity was positively correlated with e-cigarette health literacy ($r = .18$; $P < .001$). Sex was significantly and negatively associated with e-cigarette health literacy ($r = −.18$; $P < .01$), such that women reported lower e-cigarette health literacy.

Primary analyses

Covariates entered in the first step accounted for a significant amount of variance ($F[6, 312] = 9.634$, $P < .001$, $R^2 = .16$; see Table 2). E-cigarette dependence ($P < .001$) and perceived health status ($P < .001$) each had a significant effect. Step two accounted for significantly more variance in the outcome ($\Delta R^2 = .04$, $P = .001$). Step three accounted for significantly more variance in the outcome ($\Delta R^2 = .02$, $P = .02$). There was a significant interaction of pain and sex ($P = .02$). Pain positively related to e-cigarette health literacy among women ($b = .10$, $SE = .03$, $P < .001$); pain severity was not associated with e-cigarette health literacy among men ($b = .01$, $SE = .03$, $P = .60$; see Figure 1).[1]

Discussion

This study is the first to our knowledge to investigate associations between pain severity, sex, and e-cigarette health literacy among adult e-cigarette users. As predicted, there was a significant interaction between pain and sex on e-cigarette health literacy, such that pain was related to e-cigarette health literacy among women, but not men. Inspection of the interaction suggested that higher levels of pain were significantly related to *higher* e-cigarette health literacy among women, which deviated from our initial prediction. Albeit limited, some work has found that individuals who perceive their health as poorer, such as women and those with more severe pain in the current sample, are more likely to seek out health information.[46] In part,

Table 1. Descriptive statistics and correlations among variables.

	MEAN/N	SD / %	1.	2.	3.	4.	5.	6.	7.	8.
1. Sex (% female)	193	60.5%	–							
2. Age	36.82	10.62	−.01	–						
3. Income	5.64	2.05	−.19**	−.08	–					
4. Education	4.67	1.74	−.21***	−.13*	.55***	–				
5. Dual use (% dual user)	242	75.9%	−.07	.02	−.03	−.01	–			
6. E-cigarette dependence	6.98	4.02	−.02	.00	.17**	.16**	.15**	–		
7. Perceived health status	2.91	1.06	.26***	.23***	−.27***	−.36***	−.04	−.14**	–	
8. Pain severity	5.15	2.23	−.05	.07	−.08	−.03	.19***	.22***	.17**	–
9. E-cigarette health literacy	1.82	.80	−.18**	−.06	.19**	.22***	.03	.30***	.−28***	.18***

Note: n = 319; ***P < .001, **P < .01, *P < .05; Sex: 0 = Male, 1 = Female; Annual Income: 1 = $0-$4999 to 8 = $75 000 or higher; Educational Level: 1 = Grade 6 or less to 8 = Graduate or professional degree; Dual Use: 0 = No (exclusive e-cigarette use); 1 = Yes (concurrent combustible cigarette use); PSECDI, Penn State Electronic Cigarette Dependence Index;[42] Perceived health status = Short form Health Survey-12;[45] Pain severity = Hunter Integrated Pain Service – Brief Pain Inventory;[40] EHL, E-cigarette Health Literacy.[34]

Table 2. Regression model.

E-CIGARETTE HEALTH LITERACY						
	B	SE	T	P	SR²	R² CHANGE
Step 1						.16***
Age	<.001	.004	−.05	.96	.00001	
Income	.02	.02	.77	.44	.002	
Education	.04	.03	1.27	.21	.004	
Dual use	−.03	.10	−.29	.77	.0002	
E-cigarette dependence	.05	.01	4.68	<.001	.06	
Perceived health status	−.15	.04	−3.41	<.001	.03	
Step 2						.04***
Pain severity	.06	.02	3.23	.001	.03	
Sex	−.14	.09	−1.58	.12	.01	
Step 3						.02*
Pain severity*Sex	.09	.04	2.41	0.02	.01	

Note: n = 319; ***P < .001, **P < .01, *P < .05; Sex: 0 = Male, 1 = Female; Annual Income: 1 = $0-$4999 to 8 = $75 000 or higher; Educational Level: 1 = Grade 6 or less to 8 = Graduate or professional degree; Dual Use: 0 = No (exclusive e-cigarette use), 1 = Yes (concurrent combustible cigarette use); PSECDI, Penn State Electronic Cigarette Dependence Index;[42] Perceived health status = Short form Health Survey-12;[46] Pain severity = Hunter Integrated Pain Service – Brief Pain Inventory;[40] EHL, E-cigarette Health Literacy.[34]

these previous findings may help explain the observed pattern of association. Additional work is needed to evaluate the reproducibility of the current findings in an independent sample of adult e-cigarette users.

Notably, sex differences in e-cigarette health literacy were most pronounced at low levels of pain, with men reporting higher e-cigarette health literacy than women. Indeed, at high levels of pain, men and women reported visually comparable

levels of e-cigarette health literacy. These findings may result from differences in exposure to e-cigarette information. For example, men are significantly more likely to be exposed to e-cigarette information than women.[47] In turn, they may have more understanding for the intricacies of e-cigarettes and may gather information from several sources (ie, medical providers, retails, etc.) to stay informed about e-cigarettes. Women, however, may not fully appreciate these facets because of less
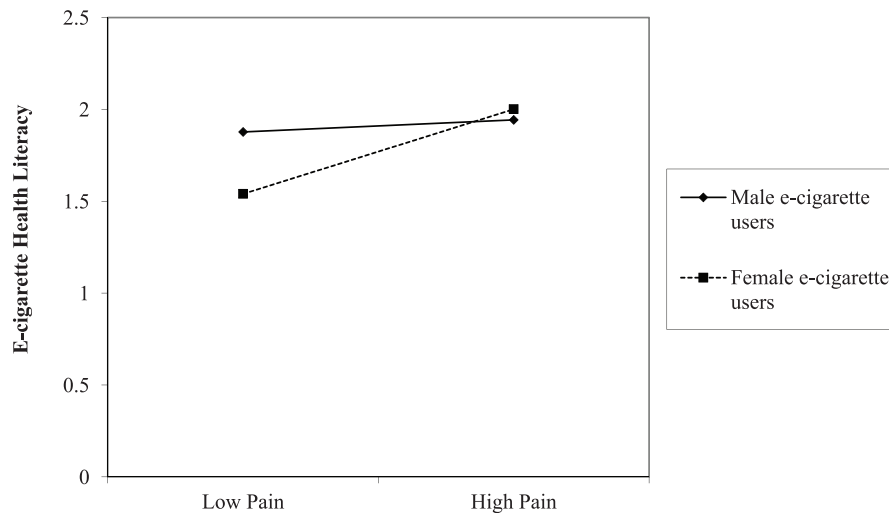
Figure 1. Interaction of pain severity and sex on e-cigarette health literacy.

exposure to e-cigarette-related information. Therefore, they may be less inclined to seek out additional information on e-cigarettes unless they already regularly seek out information on managing behavioral health or medical conditions, as may be the case with individuals who experience increased pain.[48]

Clinically, the current data provide evidence that it may be important to assess e-cigarette use across sex and levels of pain. For example, it may be useful to implement strategies that provide more information about e-cigarettes to women, specifically, to help address barriers that women may face in acquiring e-cigarette-related information. To facilitate effective communication between healthcare providers and women who use e-cigarettes and promote knowledge, self-efficacy, and self-care skills, it may be useful to use methods such as confirming comprehension through the "teach-back" method[49,50] and developing e-cigarette use interventions that are efficacious among individuals with low literacy.[51] More broadly, women who use e-cigarettes also could benefit from programs that aim to encourage e-cigarette users to stay informed about their use. Indeed, increasing awareness and knowledge about strategies to cope with underlying motives of e-cigarette use by providing personalized feedback and corrective information on the safety of e-cigarettes and comparing perceptions of e-cigarette use with normative information (eg, how others use e-cigarettes) may be a useful clinical strategy.

Several limitations should be noted. First, although our findings were statistically significant, the effect sizes of the observed interactions were relatively small.[52] Future replication of this study is needed to determine the clinical significance of the current findings. Second, this study was cross-sectional, which limits causal interpretations and the explication of directionality between the observed associations. Third, the study relied on self-report measures. Further research would profit from employing experimental or longitudinal study designs with a multimethod protocol to extend this research. Fourth, most of the sample was comprised of well-educated caucasian/white adults. As a result, the findings of the current investigation may not generalize to

individuals of all racial/ethnic minority groups or educational backgrounds. Thus, additional research is warranted to assess the proposed associations across a more ethnically/racially diverse sample. Additionally, because the outcome of interest involves literacy, replicating this study among a sample with a wider range of education levels is needed to broaden the generalizability of the current findings. Fifth, the sample was recruited exclusively via an online platform, thereby excluding e-cigarette users who do not have access to the internet. Although this method of data collection is validated,[53,54] future research could benefit from using alternative recruitment methods (eg, community samples recruited from primary care). Sixth, the presently employed e-cigarette health literacy measure is a new assessment with limited psychometric testing. Although the measure demonstrated good internal consistency in the present study ($\alpha = .85$) and initial evidence for its distinctiveness from general health literacy as evinced by unique determinants, additional research is needed to confirm the validity of this measure. Additionally, many items in this measure focus on discussing e-cigarettes with a retailer and would be less applicable for e-cigarette users who purchase their e-cigarette device over the internet, which constitutes over 25% of e-cigarette sales.[55] Consequently, future research may benefit from refining the currently employed e-cigarette health literacy and expanding items to include content related to online knowledge acquisition. Finally, although the sample reported levels of current moderate to severe pain, it was not recruited as a clinical pain sample. Thus, future research should replicate and extend these findings to e-cigarette users who present with clinical pain disorders.

Overall, the current investigation documents sex and pain severity may be relevant to better understanding e-cigarette health literacy. The present findings suggest that pain may uniquely impact the degree to which women, but not men, seek and utilize information on e-cigarettes. Future prospective studies are needed to test the impact of e-cigarette health literacy on e-cigarette outcomes, such as use severity and beliefs about use.

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Note

1. We also tested a model with general health literacy, rather than e-cigarette-specific health literacy, as the criterion variable. The interaction of pain and sex on general health literacy was not statistically significant ($P = .59$).

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